Convection Initiation and Moist Thermodynamic in the Planetary Boundary Layer: A Sounding Study of Tropical Storm Cindy by HAMSR

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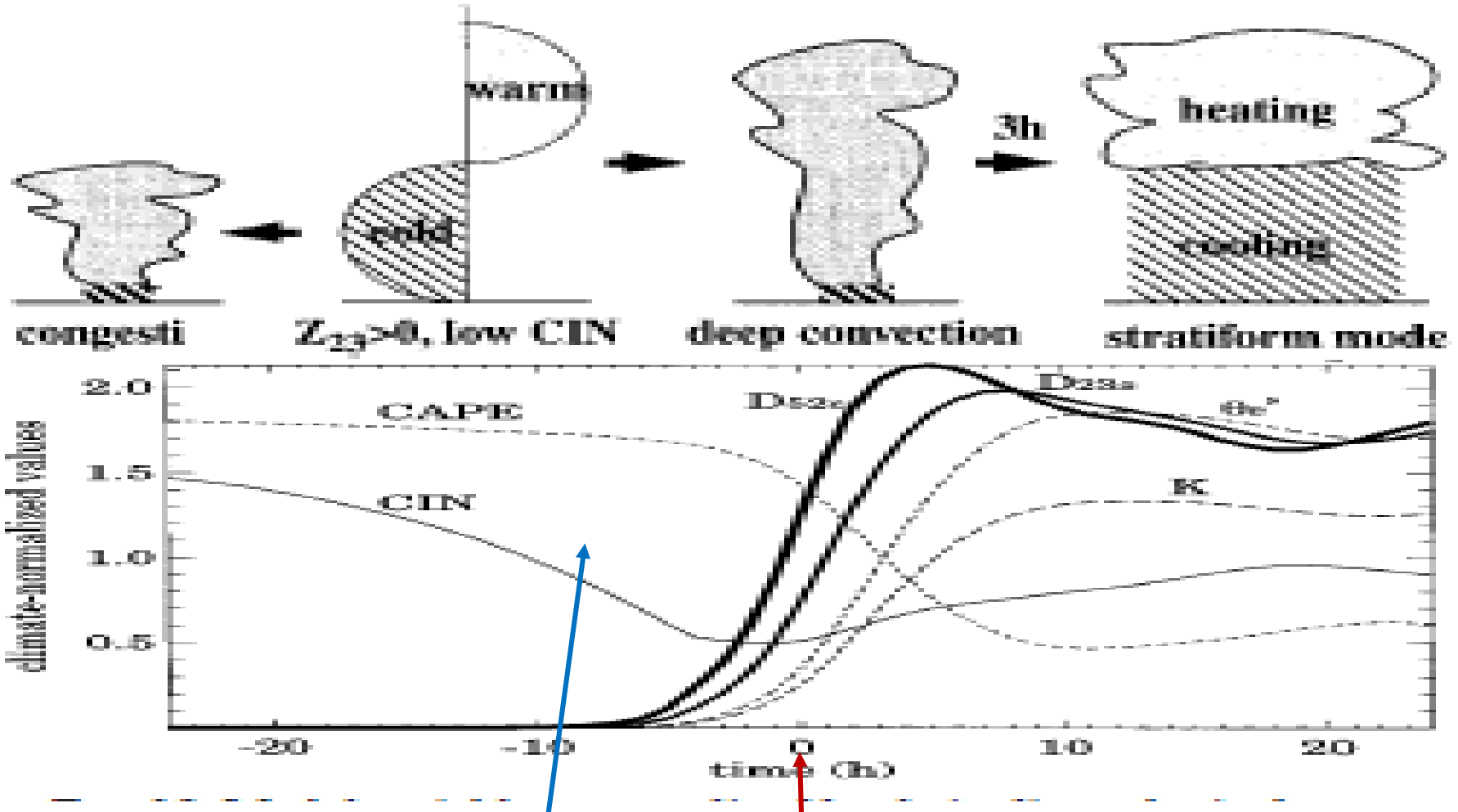
JPL/California Institute of Technology

Sounding Science Team Meeting (Maryland, 2018 October)

CIN-Controlled Convection Initiation (Mapes JAS 2000)



- A wave propagates to a region
- Lower tropospheric T cooled, congesti form
- CIN reduced, triggerring deep convection

Description of Moisture Transport

$$P - E + \frac{\partial Q}{\partial t} = -Q\nabla \cdot \boldsymbol{V} - \boldsymbol{V} \cdot \nabla Q$$

QCNVG

QADVT

Use MERRA2 for the computation

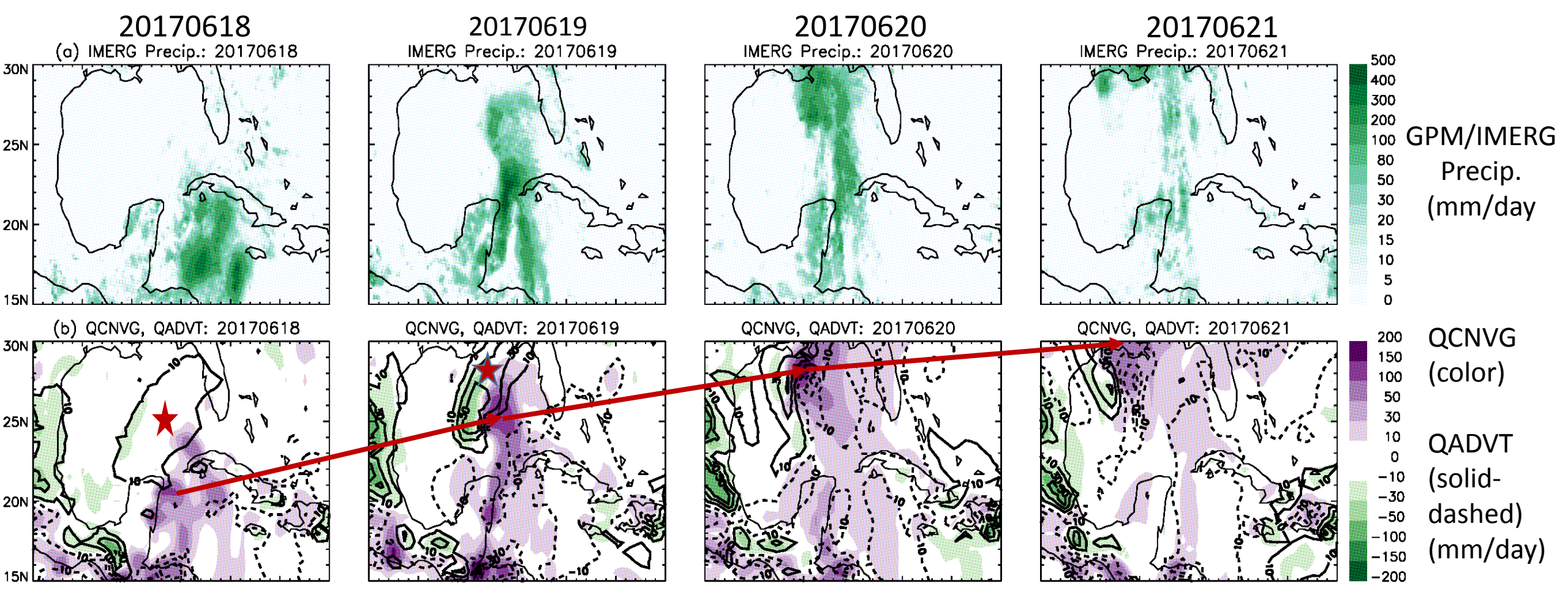
Where

$$Q = \int_{ptop}^{psrf} q \frac{dp}{g}$$

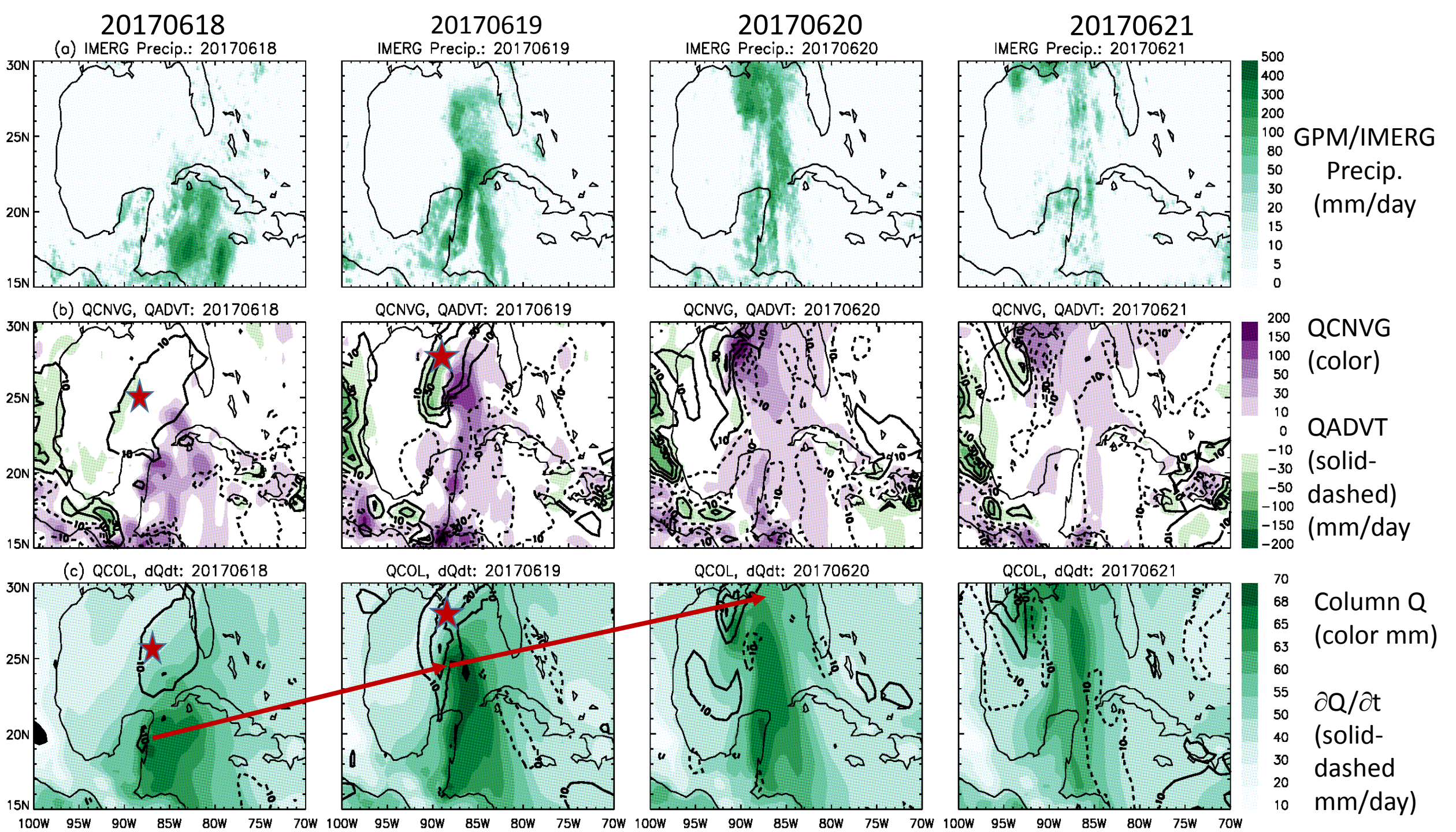
$$\boldsymbol{V} = \frac{1}{Q} \int_{ptop}^{psrf} (q\boldsymbol{v}) \frac{dp}{g}$$

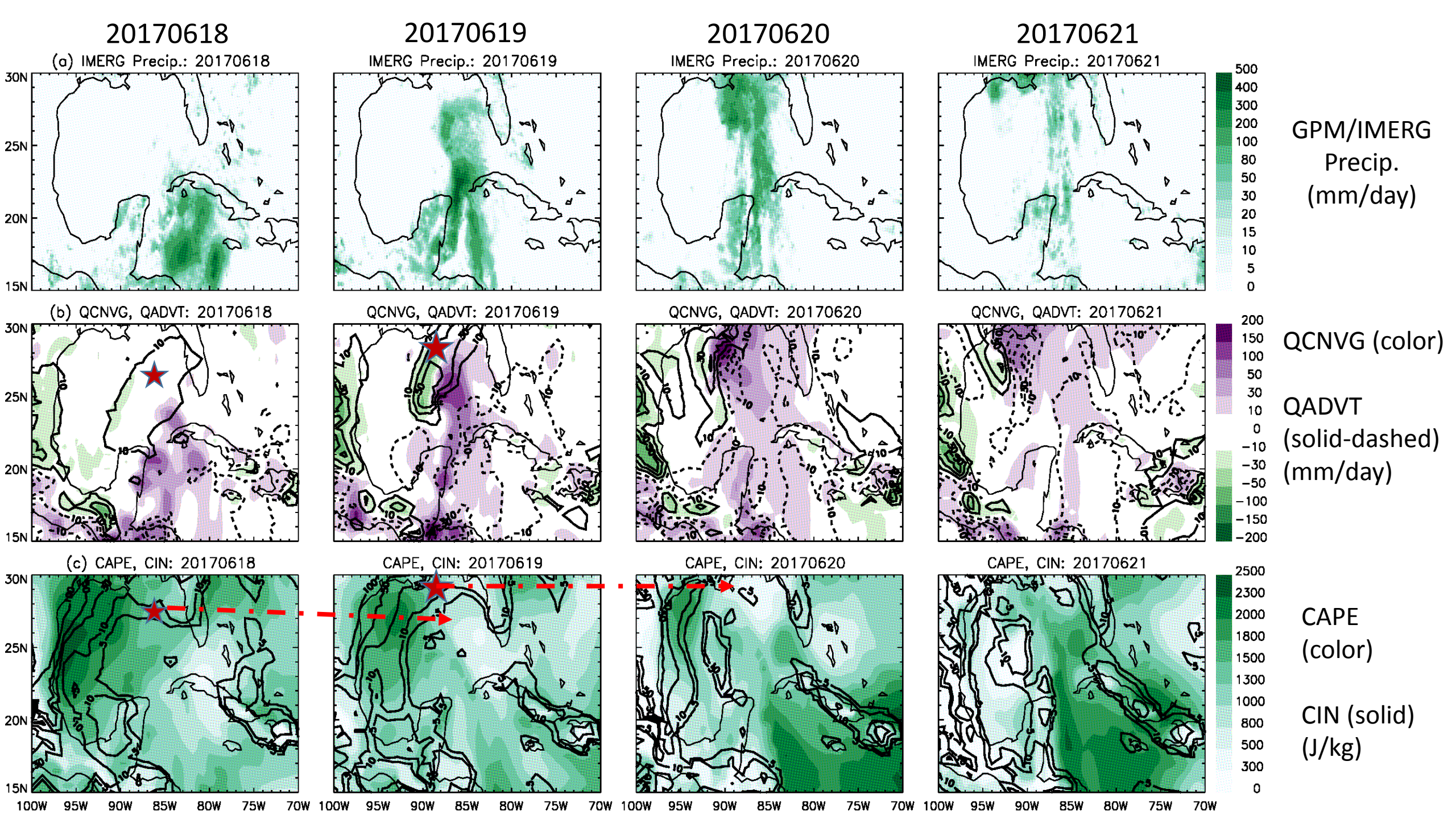
P: Precipitation
E: Evaporation
q: Specific humidity
p: Pressure altitude

(Wong et al. 2016 J. Climate)



- QADVT indicates region of preconditioning for development of deep convection


20170618
20170619
20170620
20170621
(a) IMERG Precip.: 20170618
IMERG Precip.: 20170619
IMERG Precip.: 20170620
IMERG Precip.: 20170621
(b) QCNVG, QADVT: 20170618
QCNVG, QADVT: 20170619
QCNVG, QADVT: 20170620
QCNVG, QADVT: 20170621
(c) QCOL, dQdt: 20170618
QCOL, dQdt: 20170619
QCOL, dQdt: 20170620
QCOL, dQdt: 20170621
30N
25N
20N
15N
100W 95W 90W 85W 80W 75W 70W
500 400 300 200 100 80 50 30 20 15 10 5 0
GPM/IMERG Precip. (mm/day
200 150 100 50 30 10 0 −10 −30 −50 −100 −150 −200
QCNVG (color)
QADVT (solid-dashed) (mm/day
70 68 65 63 60 55 50 40 30 20 10
Column Q (color mm)
∂Q/∂t (solid-dashed mm/day)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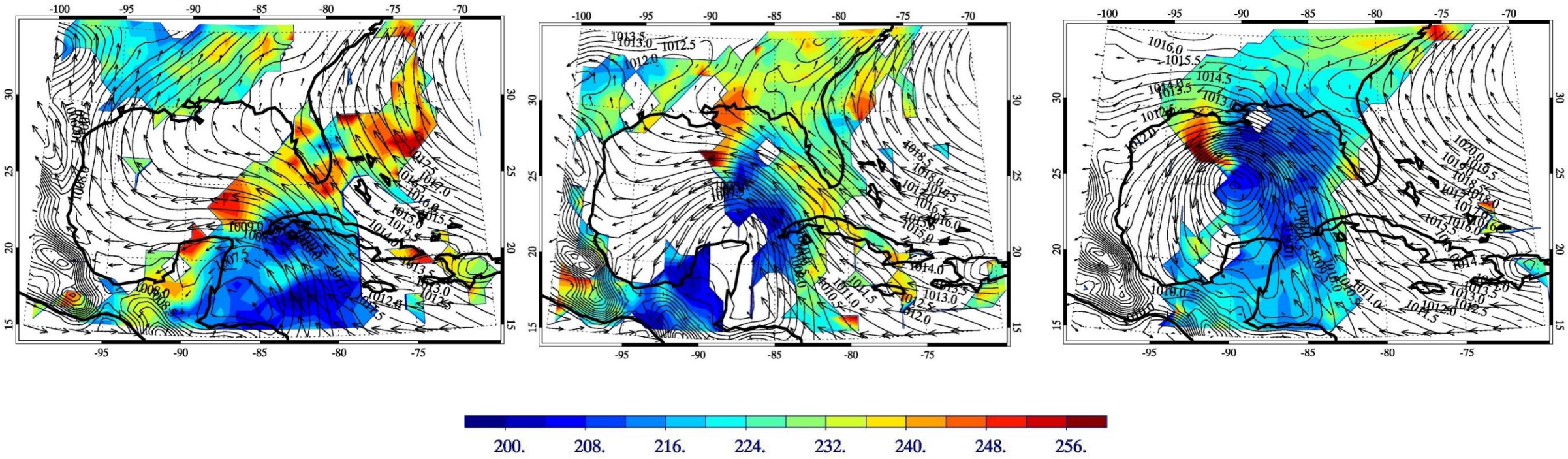
QCNVG, QADVT: 20170619
QCNVG, QADVT: 20170620
QCNVG, QADVT: 20170621
(c) CAPE, CIN: 20170618
CAPE, CIN: 20170619
CAPE, CIN: 20170620
CAPE, CIN: 20170621
30N
25N
20N
15N
100W 95W 90W 85W 80W 75W 70W
500 400 300 200 100 80 50 30 20 15 10 5 0
200 150 100 50 30 10 0 −10 −30 −50 −100 −150 −200
2500 2300 2000 1800 1500 1300 1000 800 500 300 0
GPM/IMERG Precip. (mm/day)
QCNVG (color)
QADVT (solid-dashed) (mm/day)
CAPE (color)
CIN (solid) (J/kg)

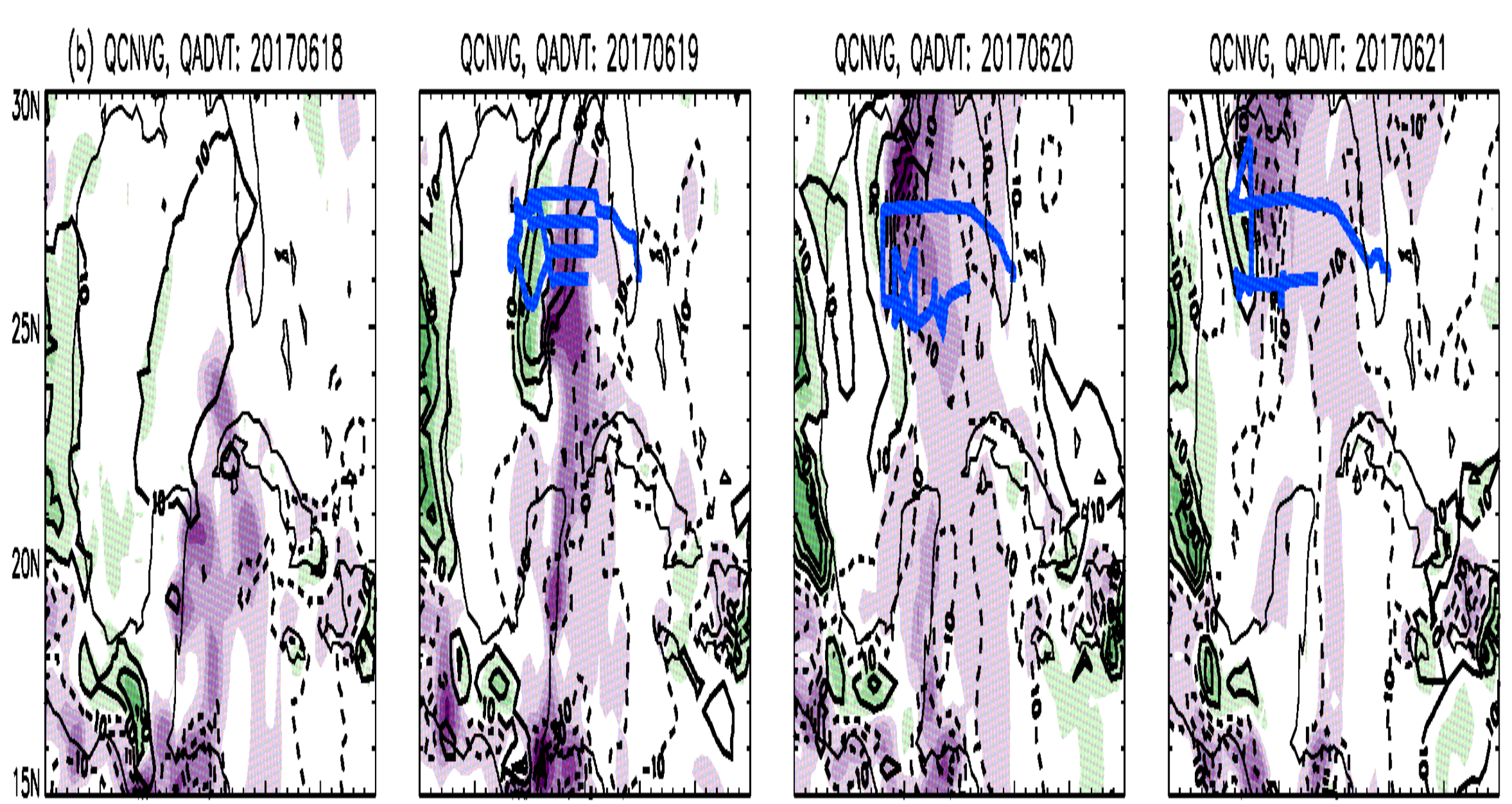
MODIS Anvil Cloud Top Temperatures with ECMWF Sea-Level Pressure
(Courtesy of Terry Kubar)

June 18
CTTs

June 19
CTTs

June 20
CTTs

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30N
25N
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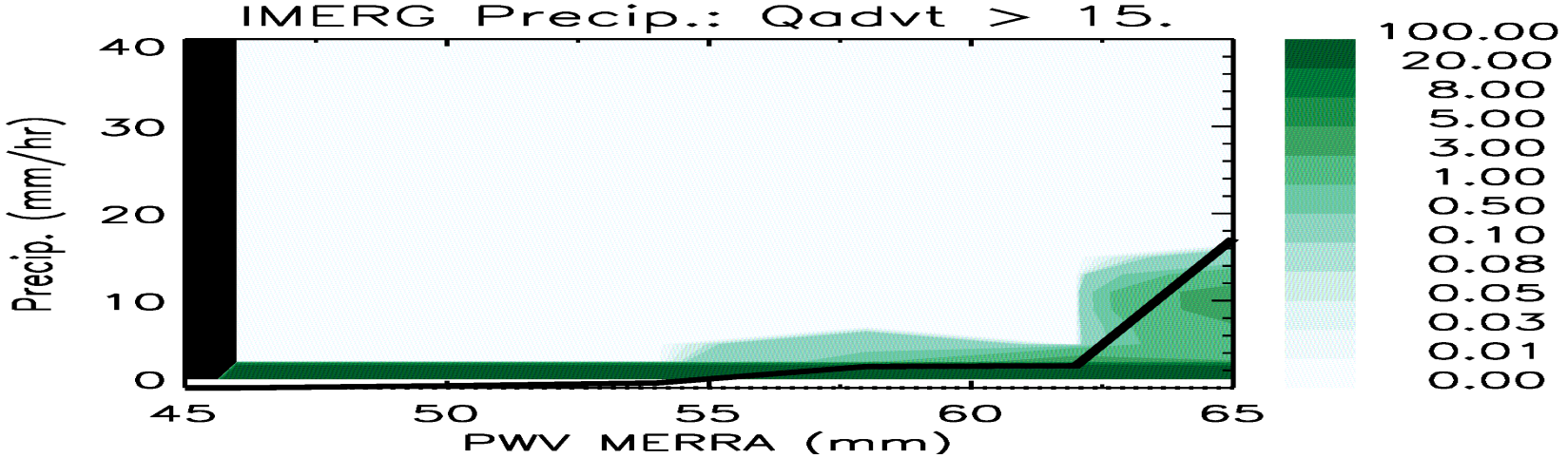
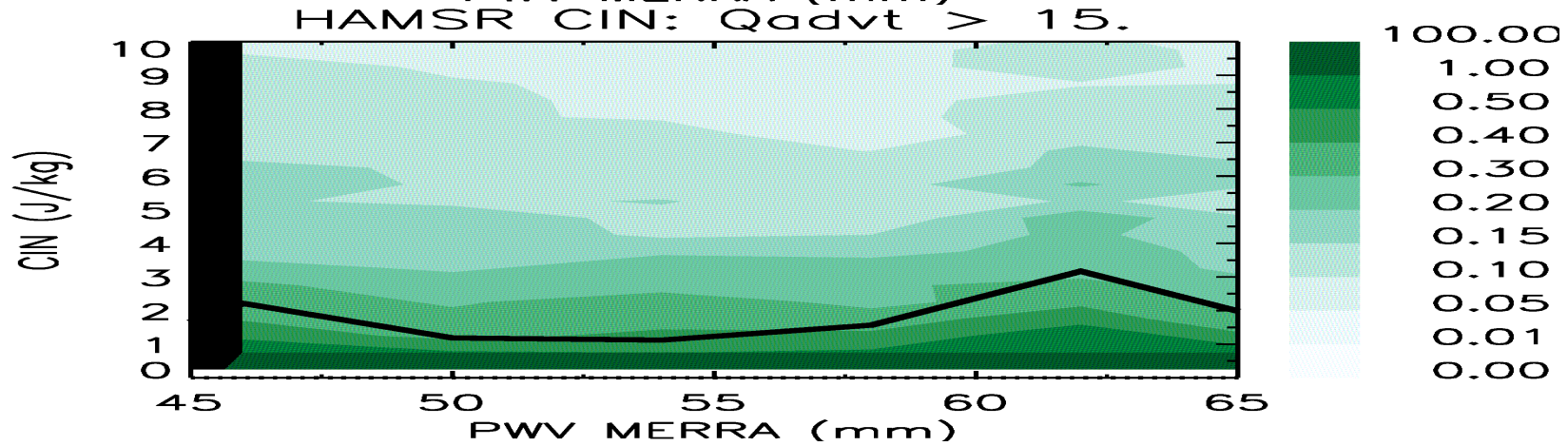
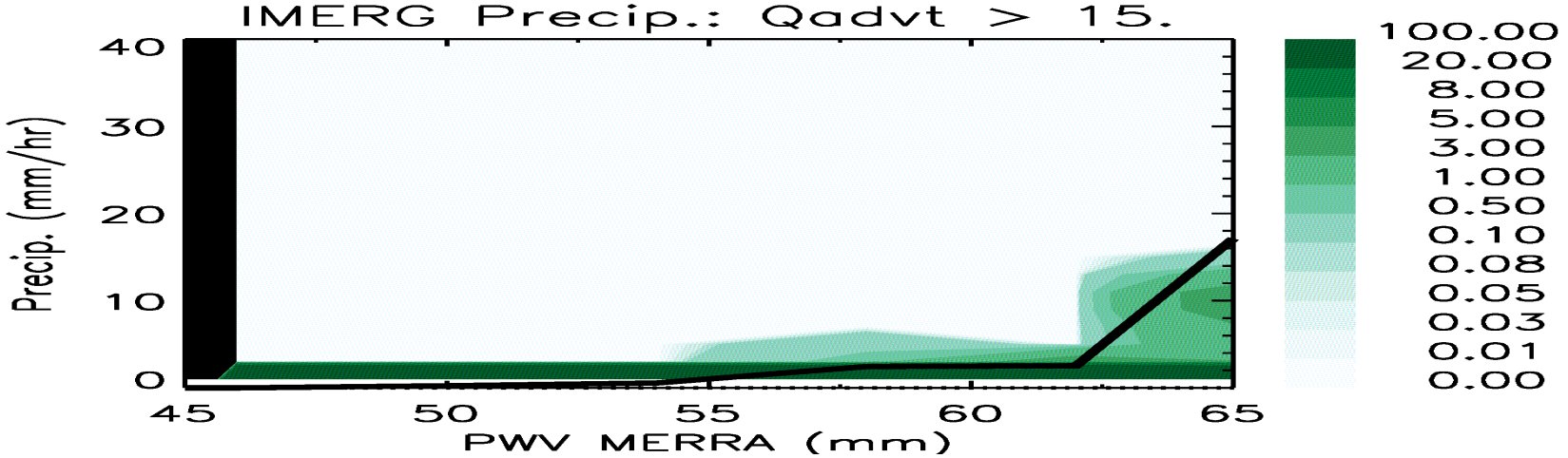
15N



- Rain (IMERG) histograms for QADVT > 15 mm/day show smaller rain
- A transition is still seen between 55-60 mm



- Countours for probability for high CIN (HAMSR) decrease between 50-55 mm



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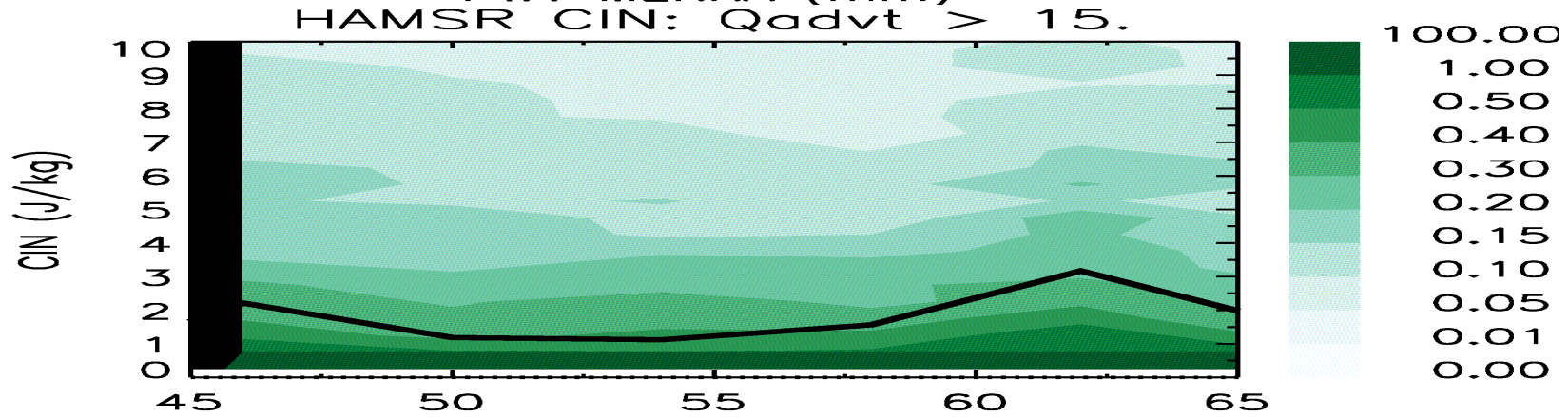

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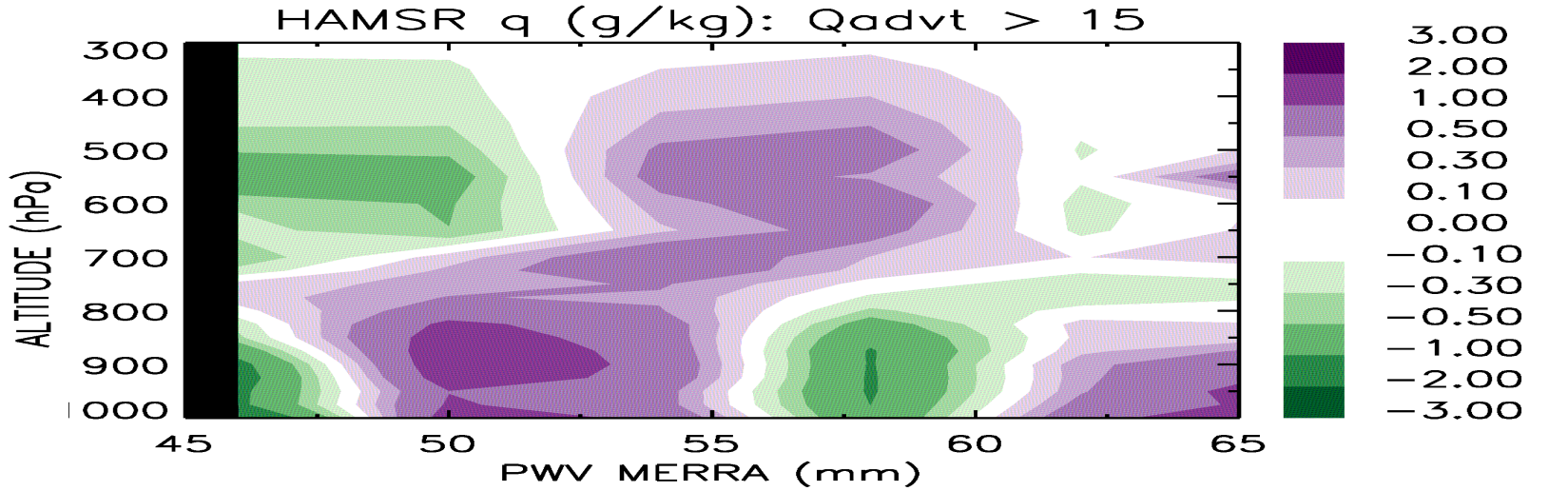
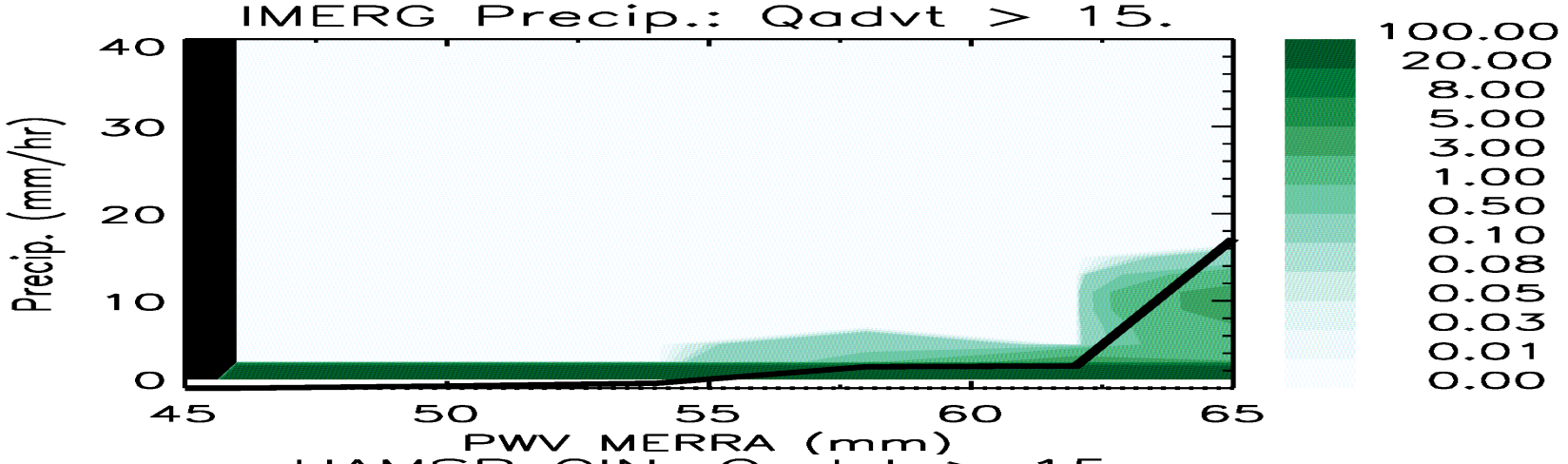


- Mid-tropospheric moistening begins around 50-55 mm and reaches a peak at 55-60 mm



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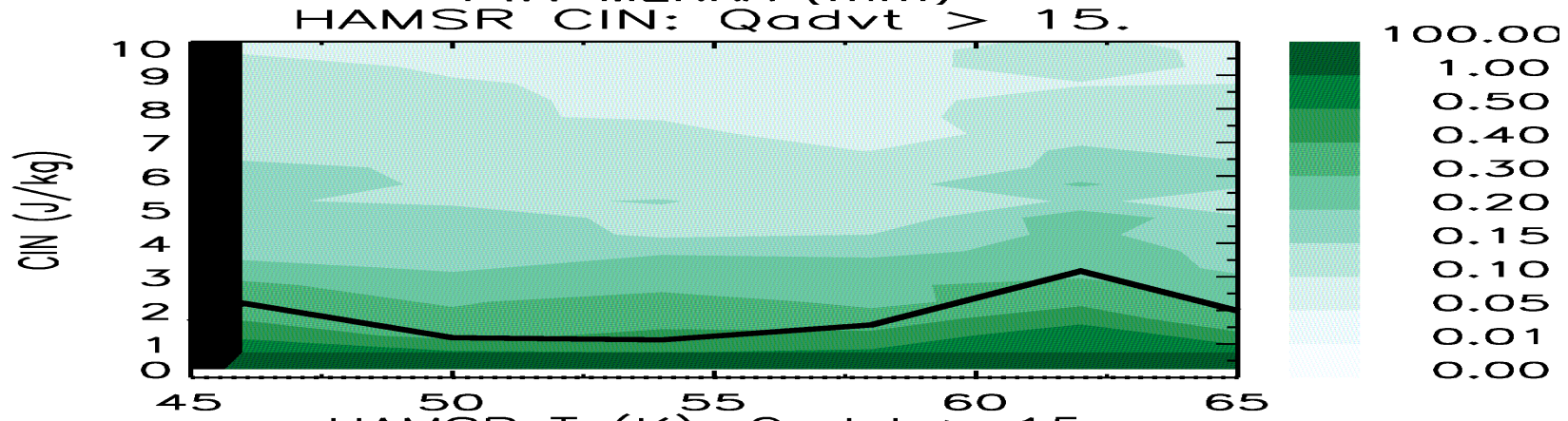

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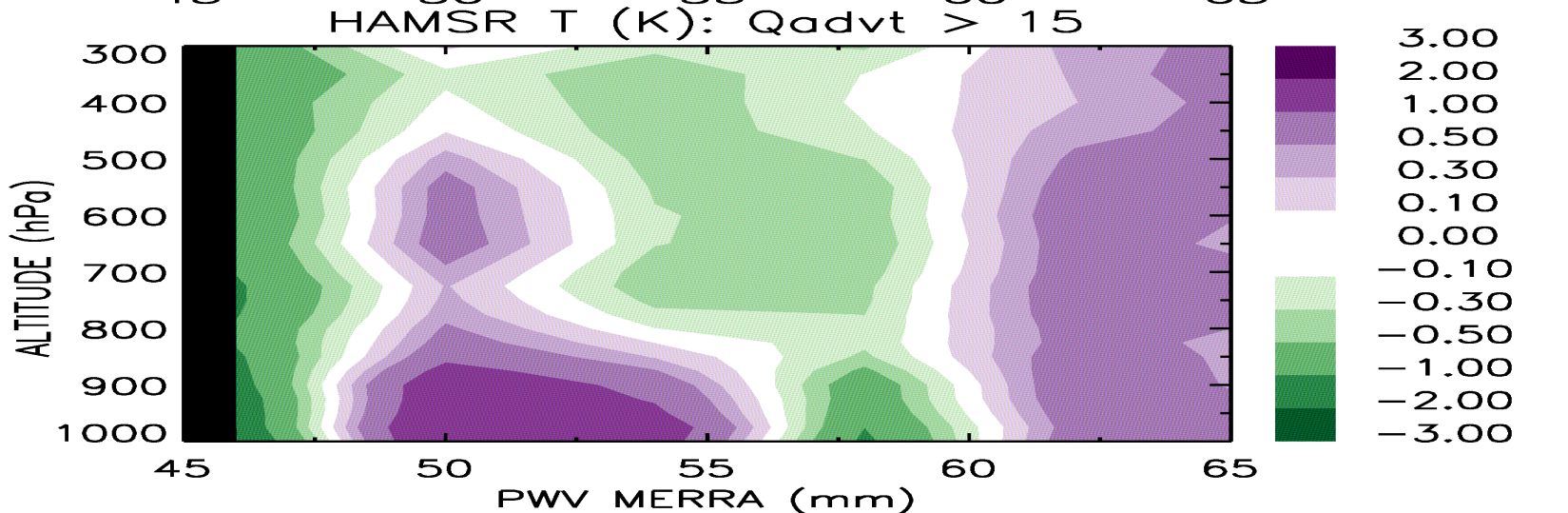
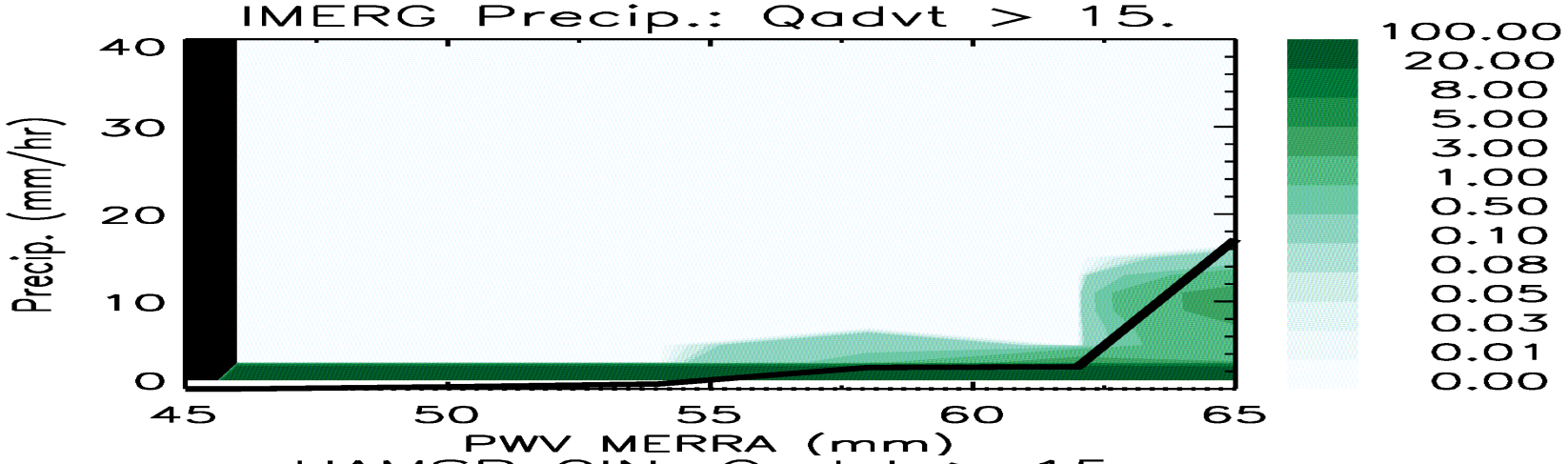
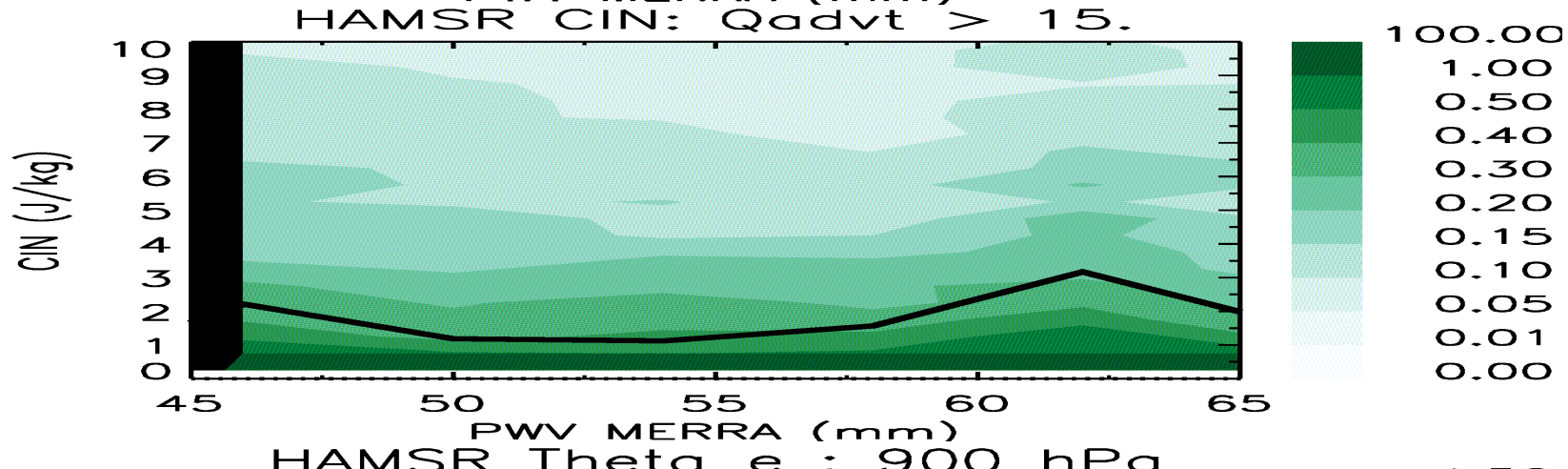
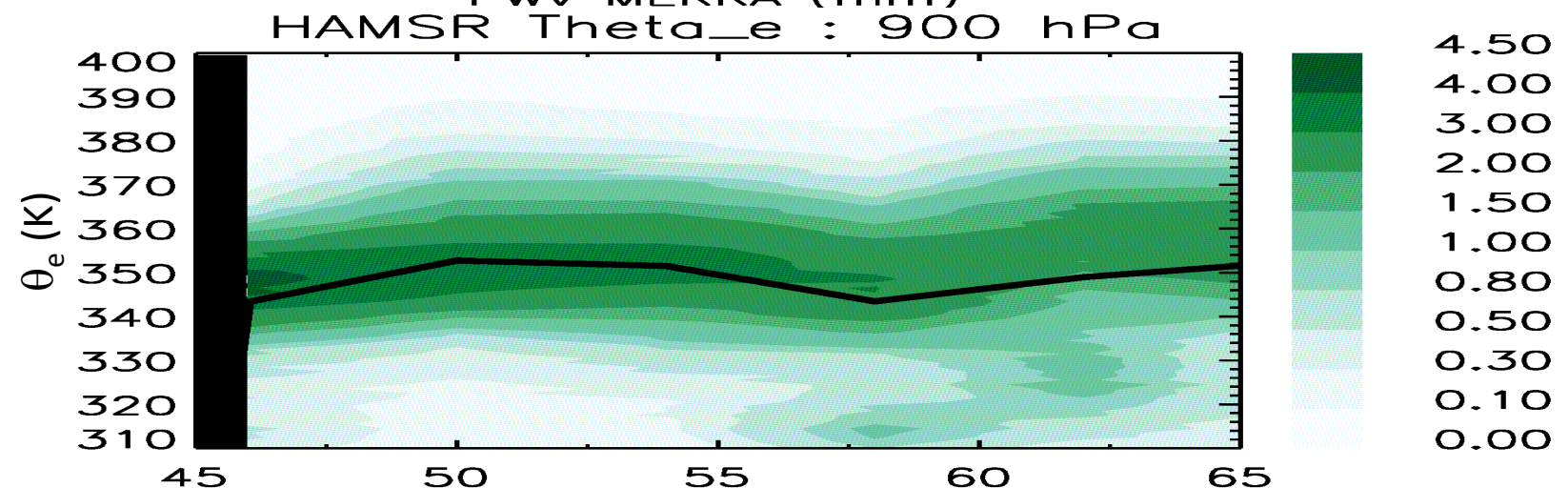


- Cooling at top of PBL begins around 50 mm and develops deeper into the PBL between 50-60 mm.







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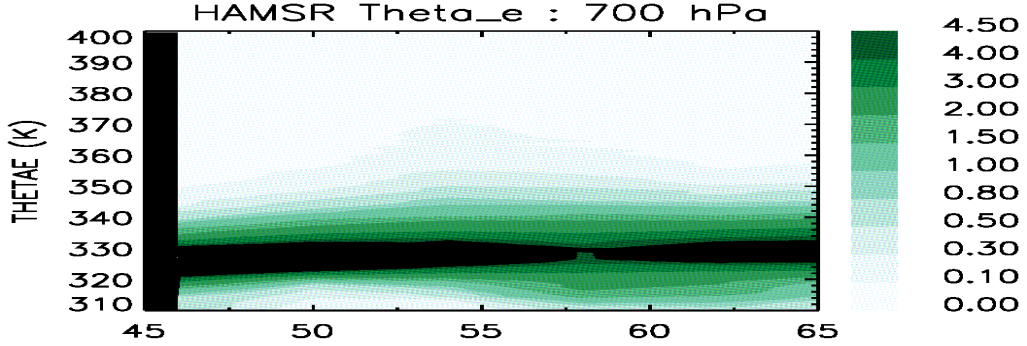
- Countours for probability for high CIN decrease between 50-55 mm

- PDF of θ_e in the PBL spreads when there begins to have rainfall.

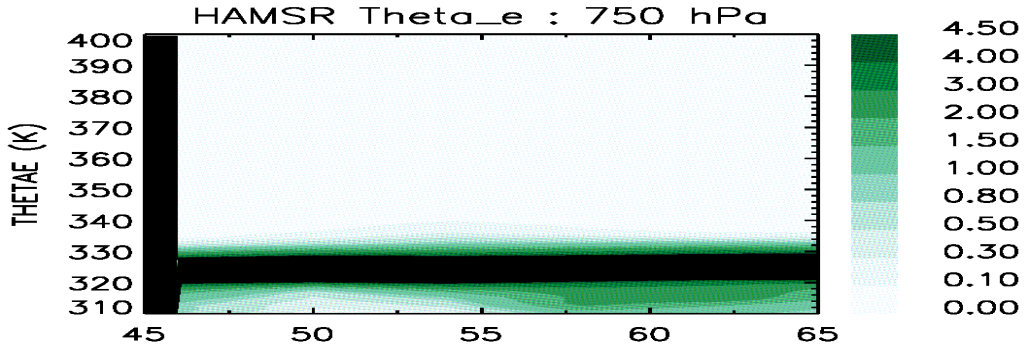
Conclusions:

- Large moist advection ($-\mathbf{V}\cdot\nabla Q$) signifies preconditioning and forebode the upcoming occurrence of deep convection
- Convection inhibition decreases with increasing moisture loading during the preconditioning period ($-\mathbf{V}\cdot\nabla Q > 15$ mm/day)
- Moist anomalies in the PBL propagate upward to mid-troposphere when Q ~ 50-60 mm
- Cooling at the top of PBL propagate downward to the surface when Q ~ 50-60mm
- Fluctuations of θ_e in the PBL are enhanced when precipitation begins

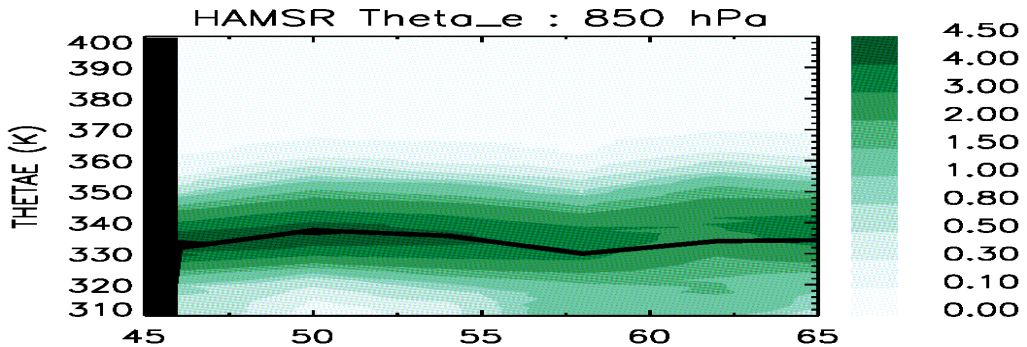
700 hPa



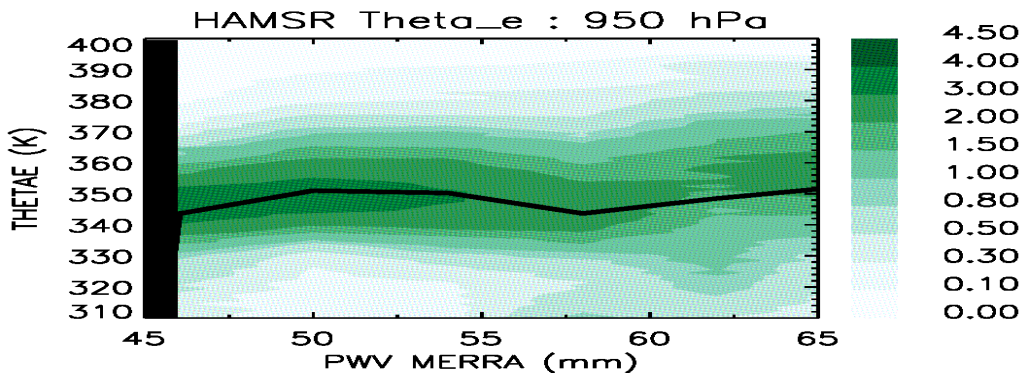
750 hPa



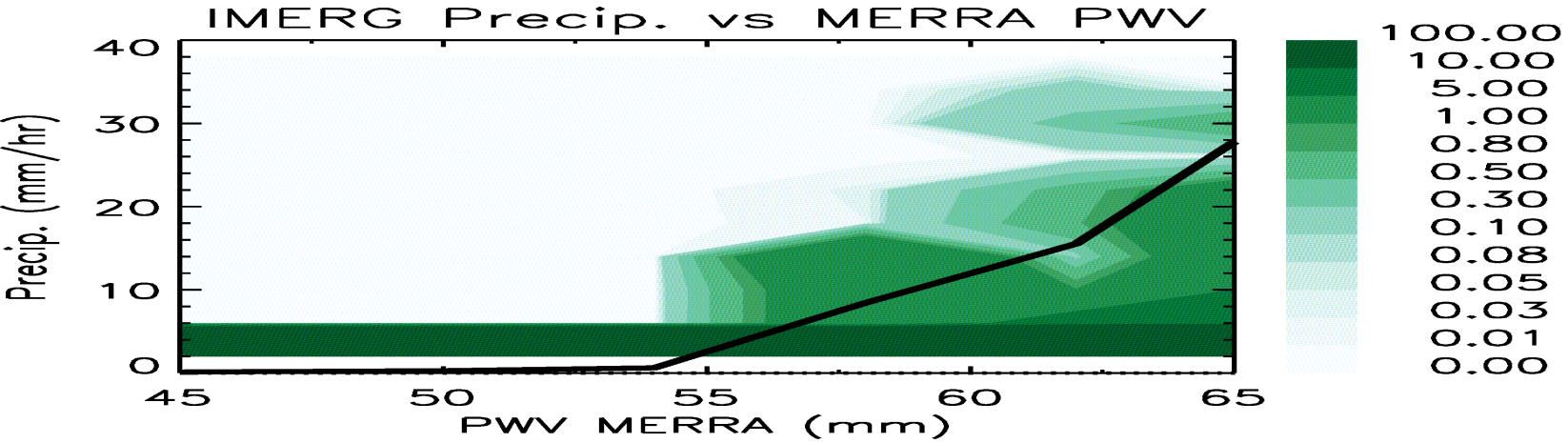
850 hPa

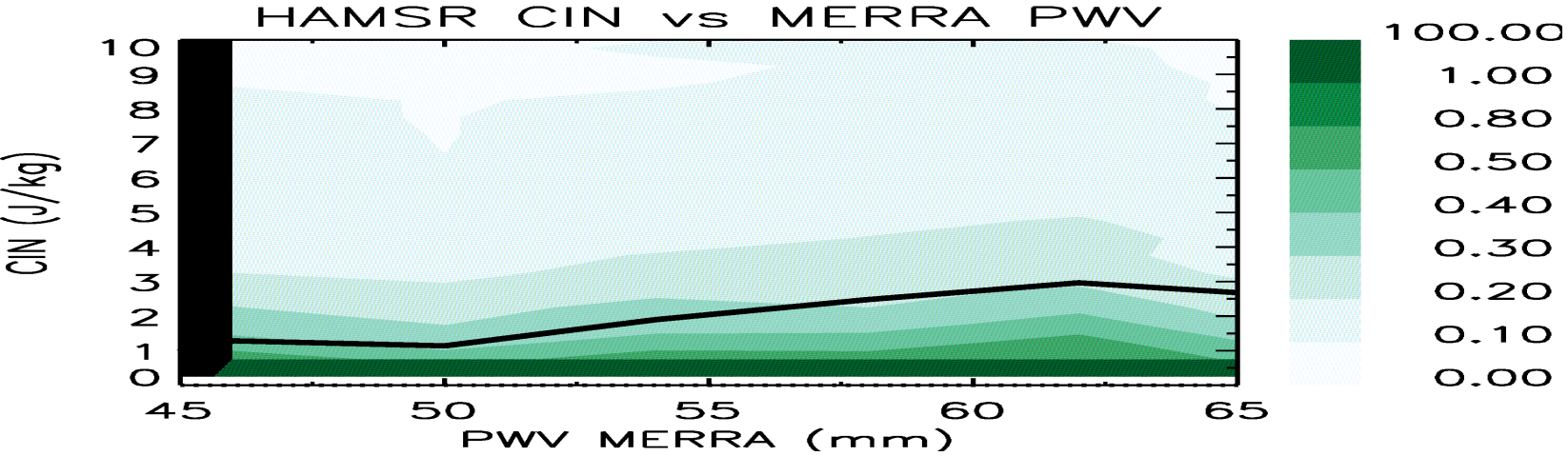


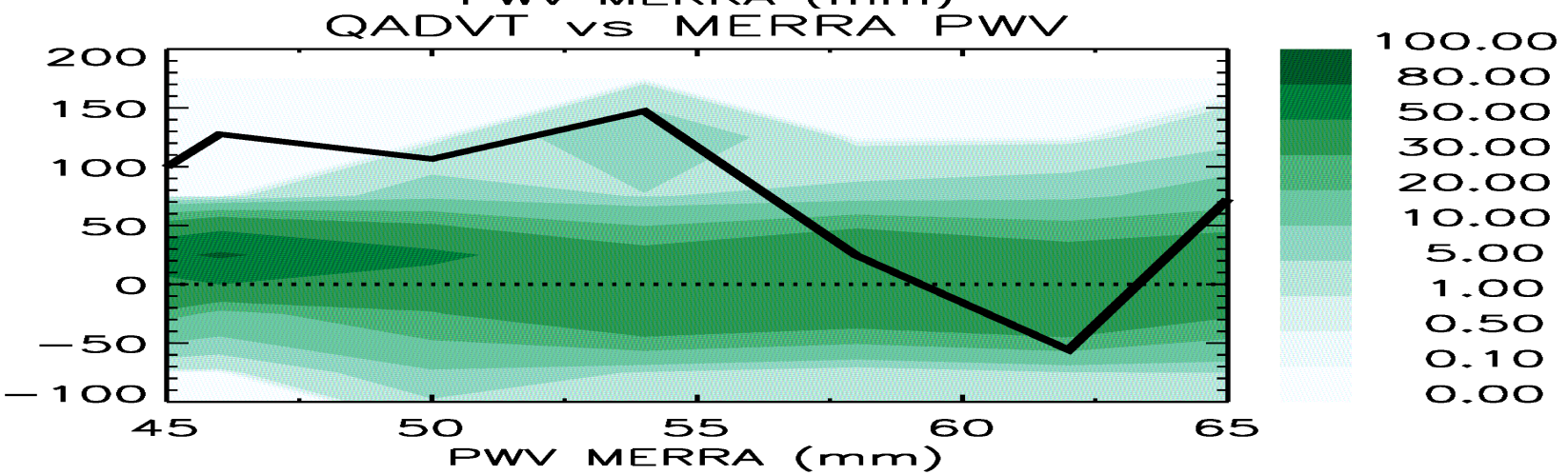
950 hPa



- θ_e histograms spread in the PBL in the raining regime. Contours of both high and low values shift to more extreme values



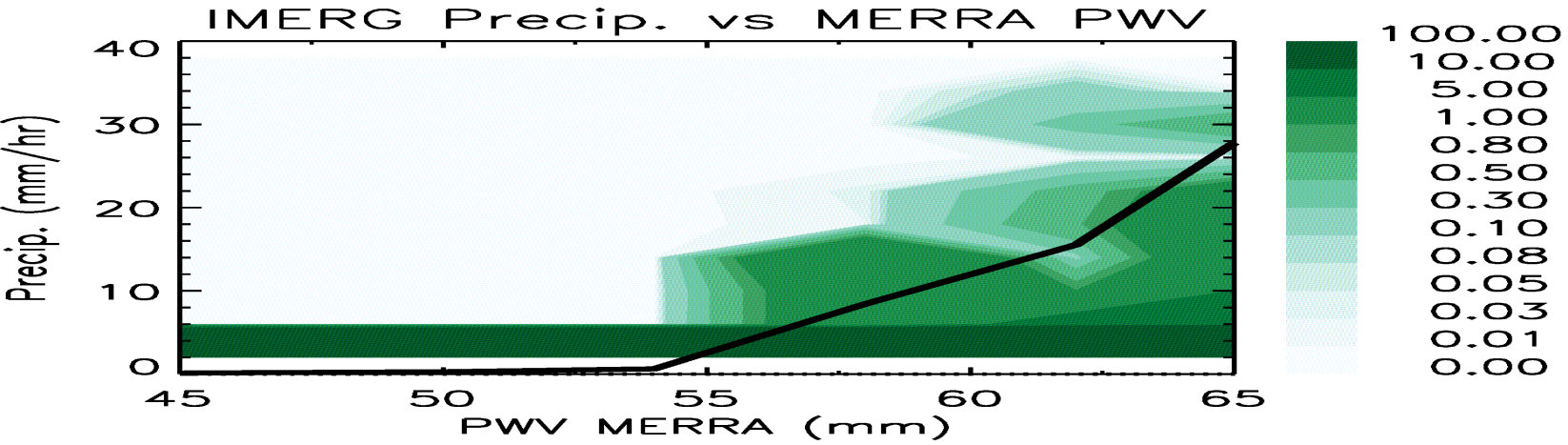




- Rain (IMERG) histograms as a function of MERRA-2 precipitable water vapor (PWV)
- A transition is seen between 55-60 mm

- Nope! CIN (HAMSR) reduction is not obvious before 55-60 mm

- Need to pick preconditioning condition with QADVT > a positive threhold



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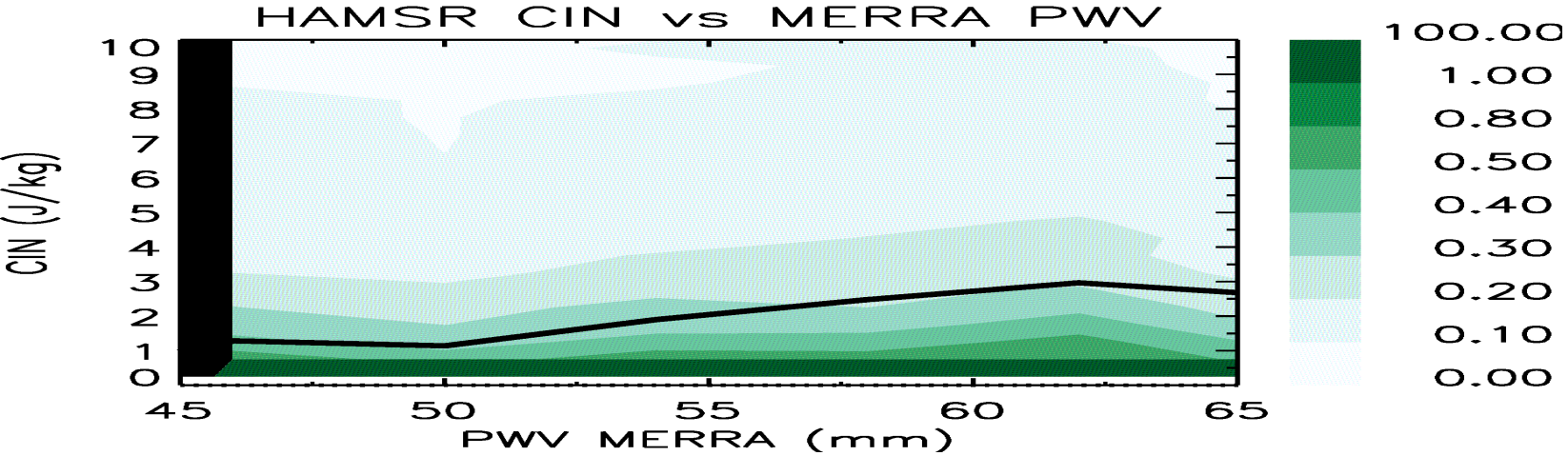

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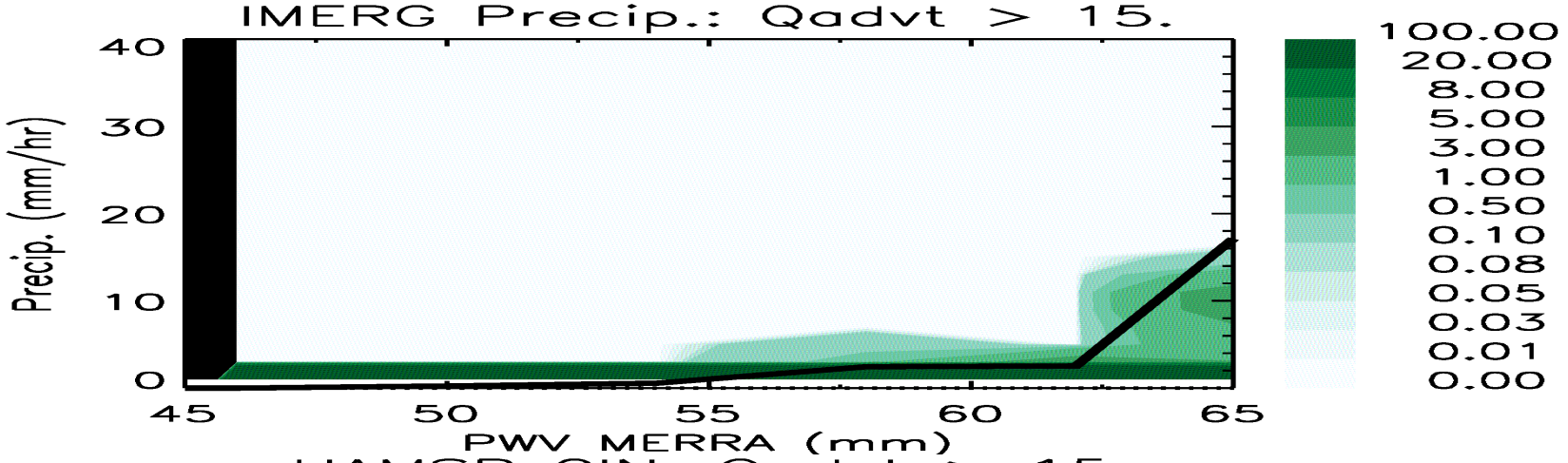

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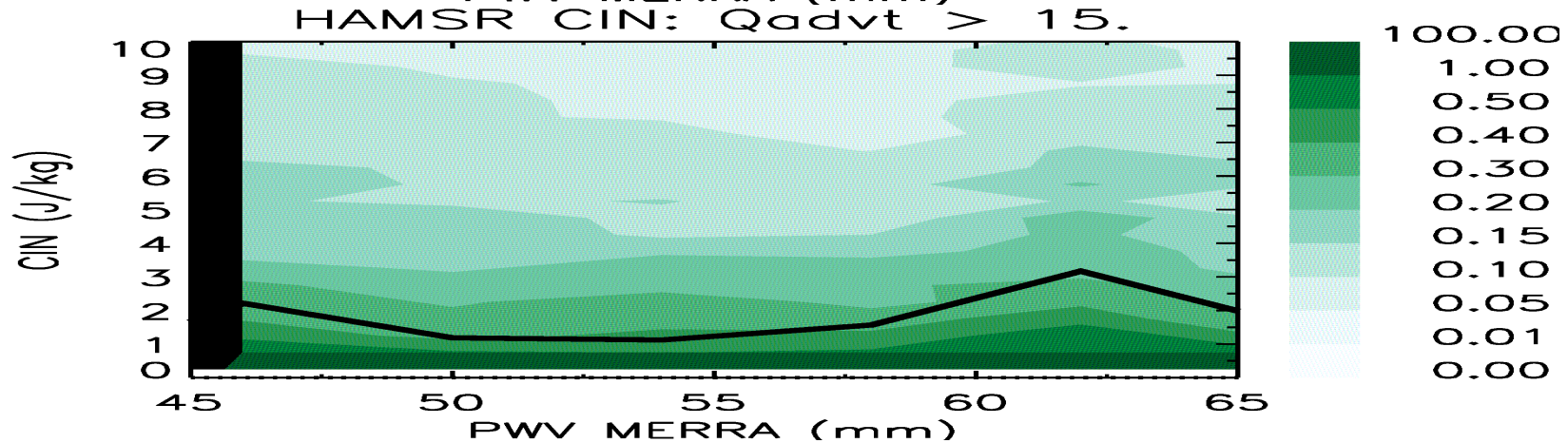
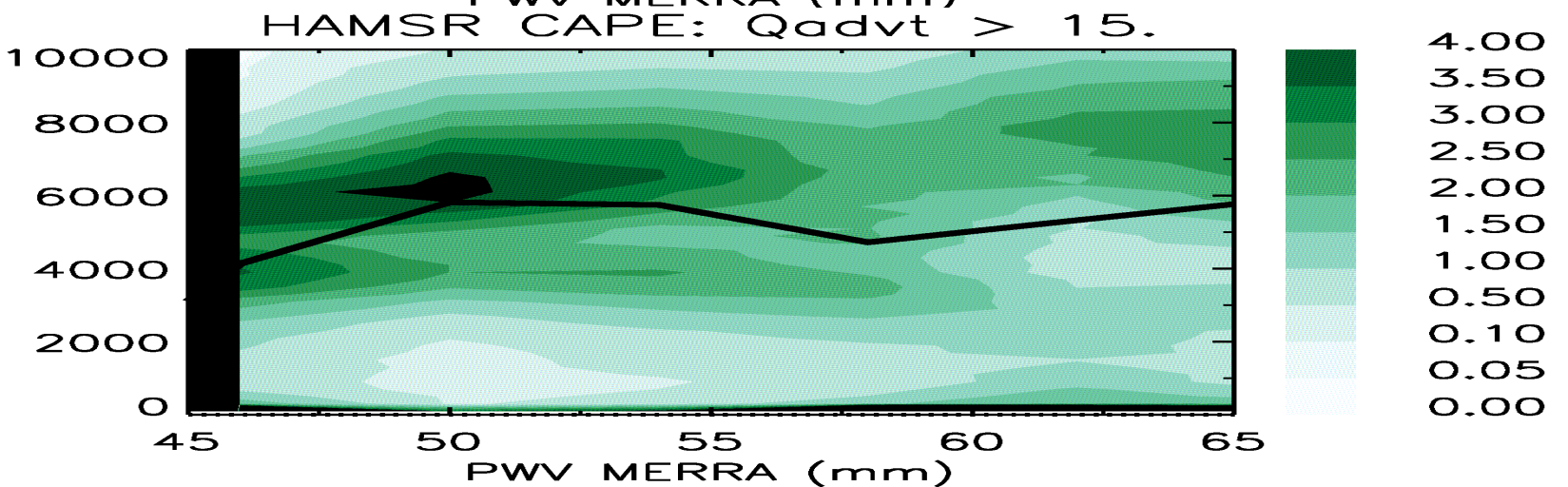


- Countours for probability for high CIN decrease before 55 mm



- Averaged CAPE remains steady between 4000-6000 J/kg
- A bifurcation in CAPE histograms before 55 mm